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Generation of electric energy in isolated rural communities in the Amazon Region a proposal for the autonomy and sustainability of the local populations

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ABSTRACT

The Brazilian Amazon Region is living with the consequences of governance based on predatory extraction of its natural resources, bringing little or no benefit to the local population. The region suffers from socioeconomic inequality and lack of basic infrastructure. The populations of the Amazon Region, if and when supplied with electricity at all, are provided with a low quality service based on energy generation from fossil fuels, subject to difficulties in terms of access and logistics, and negative environmental impacts. There have been programs aimed at the universalization of electricity services, such as the current Programa Luz para Todos (Light for All Program), but they have not succeeded in altering this scenario in the North region of the country. In this paper we present the result of these initiatives and an overview of the Isolated Systems in the Amazon Region. We propose in this paper that the provision of electric energy be effectively considered part of a plan for generating wealth and employment for the region's inhabitants, whilst preserving the environment. The solutions offered to each community should take into account the need to manage renewable energy sources, should be developed together with local populations, and drawing on the lessons learned from other projects. The specific characteristics and needs of the communities should be taken into account and local people should be empowered as citizens by means of their involvement in the development possibilities.

Contents

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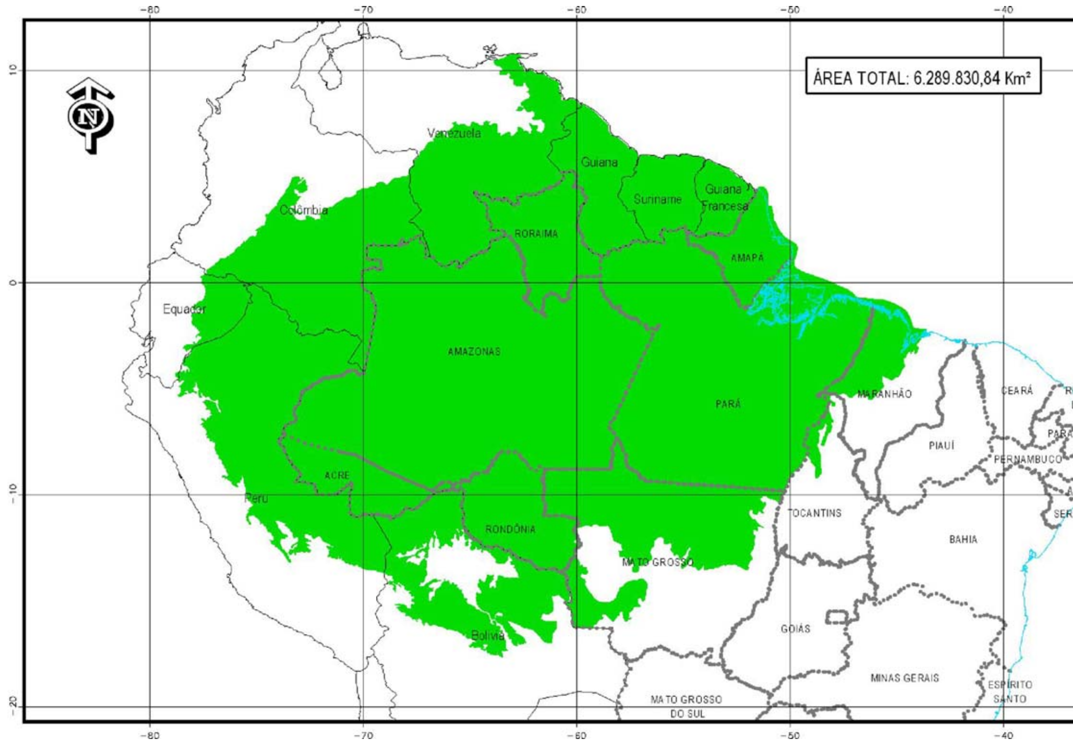


Fig. 1. The Amazon Region ("Amazonia").Source: Elertobás/Ministry of the Environment/U.S. Geological Survey.

1. Introduction

The Amazon Region, in South America, is defined by the basin of the Amazon River, and largely covered by tropical forest. The Amazon Region biome (Fig. 1) occupies a total area of approximately 6.3 million km^2 of which approximately 4.1 million km^2 lie within Brazilian territory.

Representing around 7% of the world's vegetation cover, Amazonia is home to over 50% of all life forms that exist on the planet, including plant species, anthropoids, birds, fish, mammals and the most basic microscopic life forms. The region also contains 20% of the world's non-frozen water supply, and 80% of the water available within Brazilian territory. This abundance of water sustains the world's largest tropical forest, which in turn plays an essential role in maintaining the water cycle and local and world climate equilibrium.

The Amazon hydrographic basin has several important tributaries, such as the Rio Negro, Rio Tapajós and Rio Madeira. The principal river is the Amazon itself, which, from its source in the Andes, crosses eight countries before flowing into Brazilian territory. It is considered the world's most voluminous river, depositing between 200,000 m^3 and 220,000 m^3 of water per second into the Atlantic Ocean.

The fluvial regime is of paramount importance to the life of the inhabitants of rural Amazonia. It impacts on their livelihood and subsistence, housing, leisure, their relationship with nature and all social and economic activity [1].

There is marked disparity between the urban (state capitals) and rural areas of the region. The local economy has a strong extractivist component, and a low rate of industrialization coupled with lack of basic infrastructure. The lack of opportunities for economic growth and development has contributed to demographic outflow.

One of the explanations for the unequal growth of the region is that the towns and villages are isolated, and do not form integrated region-wide economies. Most of the population is concentrated in the state capitals and other urban areas, as is economic development, so that the hinterland suffers from severe lack of assistance.

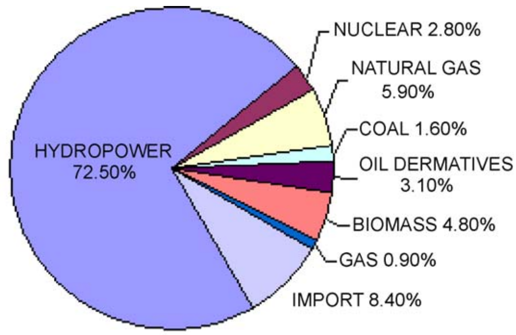
Amazonia is living with the consequences of a model based on predatory extraction of forest resources [2], leaving poverty in its wake. The local populations, who have limited access to information and education, do not actively participate in the definition of priorities for the societies in which they live.

There has never been a proposal for the region effectively focused on development for local populations. There is a line of thought that advocates preserving the region's natural resources intact, as a *world sanctuary,* freezing the growth of local populations, given that development, in this context, is incompatible with environmentalism. As a result, however, the region has been neither preserved nor developed, and suffers from destructive exploitation [3].

Reality shows us that preservationist environmentalism does not generate wealth, employment or income to meet the demand existing in the region where the natural resources are located. On the other hand, the natural resources themselves, used in a manner compatible with conservation i.e. observing the time required for replenishment and respecting local culture, offer hope of socially inclusive sustainable development of local societies.

We argue, in this paper, in order to ensure that the benefits of Brazil's natural wealth remain in the region, for priority to be given to sustainable management of the resources in a planning strategy that takes into account the specific characteristics of each population group and which promotes their autonomy. Such a Program, to be implemented in the region should, taking into consideration the issues addressed in this article, feature adequate legal measures and instruments, financial resources for the initiatives and contain, as an essential element, the empowerment of local people, respecting their history, needs and ambitions.

Electricity *per se* is not a vector for development. Even if it is able to provide changes in the quality of life of the populations supplied, it is not in itself sufficient to lead to their emancipation. The plan for universal access to electricity should contain instruments



Source: MME, Resenha Energética – Exercício de 2008 – Preliminar – Março 2009

Graph 1. Matrix of electricity supply – Brazil – 2008.

enabling rural families to acquire the knowledge and skills that will enable them to assume control of their own development.

2. Rural electrification in the Brazilian context

The model of electricity supply implemented in Brazil in recent decades gave precedence to the generation of hydroelectricity from major developments and to the transmission of voluminous blocks of energy. In terms of installed generation capacity, hydroelectric plants account for over 365.1 TW h, around 72% of the production, as can be seen from Graph 1*:*

This model led to an electrification rate of over 90% in Brazil, with electric energy being the most widely available public service, as can be seen from Chart 1.

The access to electricity indicator has led to Brazil being ranked higher than other Latin American countries on the human development index (HDI). Electricity naturally brings about improvements in several social indicators such as health, life expectancy and education.

Households situated in the North of the country, however, have significantly less access to these services when compared to other geographical areas.

Worldwide around 99% of people who do not have access to energy at home are concentrated in the developing world, and 80% of non-electrified households are located in rural zones [4].

In Brazil, 90% of families who do not have access to electricity at home have an income equivalent to less than three minimum wages. Around 33% of these earn less than one minimum wage.[3]

In rural areas the challenge of electrification needs to take into account certain essential characteristics such as [5]:

- Wide spatial dispersal leading to difficulties in terms of logistics, time and cost of transport, access to communication services and the viability of electrification projects proposed by public service concessionaires.

SERVICE	BRAZIL
Electric lighting	98.2
General Mains Water Supply	83.3
Sanitation/Sewerage Service	73.6
Garbage Collection	87.5

Source: Pesquisa Nacional por Amostra de Domicílio - PNAD/IBGE, 2007

Chart 1. Services available to households – Brazil – 2007 (%).

[3] Brazilian Minimum Wage as of February 1, 2009: R$ 465.00 = US$248.13 (August 28, 2009).

- Non-integration into the formal economy, complicating the diffusion of goods and services into and between communities.
- Low human development indicators, with limited public services leading to e.g. lack of water treatment, sanitation, health services, education and electricity.
- Low income rural dwellers have a pattern of low energy consumption which provides little return on investment in this sector.
- The high maintenance costs incurred by concessionaires, aggravated by the long distances to be covered.

Several public programs aimed at ensuring universal access to electricity in rural areas have been launched, with modest results to date in the remote and isolated areas of Amazonia. The *Programa Luz para Todos* (Light for All Program) is currently underway.

- Energy development program for States and Municipalities – Prodeem

Prodeem was established in 1994 by the Ministry for Mines and Energy with the main objective of supplying rural communities that were not connected to the conventional electricity distribution network. It operated via de-centralized generation systems based on renewable energy sources, providing electricity for schools, health centers and other community installations.

The Prodeem technologies included photovoltaic solar energy, wind power, small hydroelectric plants, and fuels derived from biomass and biodigestors. Photovoltaic technology predominated, and between 1996 and 2002 approximately 5.2 MWp was installed and distributed in over 8700 photovoltaic solar energy systems.

The Program however accumulated a series of management problems and several systems were lost as a result of the centralization of decisions, lack of preparation, training and organization of the communities to receive, operate, maintain and be responsible for the equipment.

- National program for rural electrification – *Luz no Campo* (Light for the Countryside)

The *Luz no Campo Program*, Light for the Countryside Program, was set up in December 1999, with the main objective of increasing the level of electrification in the hinterland, as a means of establishing basic conditions for the expansion of farming and for contributing to the socioeconomic development of rural areas.

The Program had a target of supplying electricity to around one million rural dwellings and properties between 2000 and 2003. In this context, it was to benefit five million rural dwellers that did not use electricity at home or in their agricultural production units.

The *Programa Luz no Campo – LNC* concentrated on the expansion of the network, in which rural consumers would use long term financing to pay for the connection charge.[4] The LNC Program was, at the time, the largest rural electrification program set up in Brazil, with approximately 630,000 connections between 2000 and 2003, an average of 157,500 connections/year.

2.1. National Program for Universal Access and Use of Electricity Programa Luz para Todos – PLPT-"Light for All Program"

Set up in November 2003, to substitute the Light in the Countryside Program, and in accordance with Law 10.438, the main objective of the Programa Luz para Todos is to supply and distribute electricity to all rural dwellings and establishments, with no connection charge to the consumer, by 2010.[5] The aim is to serve 12 million Brazilians in over two million households that do not as yet have access to electricity.[6] Furthermore, the PLPT aims to improve the quality of the service offered to the target population, to expedite the expansion process and to mitigate the potential impact of tariffs by allocating earmarked funds (CDE)[7] and by the topping up of financing schemes (RGR).

The Scope of the Program defines the following priorities, amongst others:

- Rural Settlements, Quilombolas (historical settlements founded by escaped and freed slaves), the Lands of Native (Indigenous) populations.
- Communities affected by hydroelectric dams.
- Municipalities where there is electricity supply to less than 85% of the population.
- Municipalities with a low Human Development Index.
- Public schools, health centers, and public water supply wells.
- Rural electrification projects in aimed at collective demand.

A budget of 13 billion reais[8] was set aside for the PLPT. Priority was given to the number of connections and the extension of the existing network, which further delayed provision to isolated communities in remote areas of the country, where the cost of installing transmission lines compared to the return available is a disincentive.

During the early years of the Program, the simultaneous demand for equipment in several states led to unforeseen increases in the cost of equipment for transmission lines and related services. In some cases supplies ran out.

The PLPT has made little use of renewable sources or distributed generation, and offers no real prospects for the sustainable development of the population groups served.

Management of the Programa Luz para Todos is divided between various bodies and governmental organs: state governments, energy distributors, ministries, agents in the electricity sector and communities.

A Directive from the Ministry of Mines and Energy (MME) issued in February 2009 published the Special Projects' Manual covering the basic guidelines for rural electrification projects aimed at supplying locations distant from the current distribution networks, and difficult to access, particularly those in the Amazon Region (Amazônia legal).[9] The guidelines provide for supply via the generation of electricity from renewable sources, to an extent that is compatible with local reality. This initiative demonstrates the need for a response to the major challenge of electrifying all households in the country. New projects should make provision for minimum capacity capable of meeting the basic needs of households, such as lighting and communication, together with possible refrigeration/cooling. The earlier projects under the Program provided in some cases for sufficient energy for lighting and television only.

Research undertaken in the country [6] has revealed that electricity improved the living conditions of the population in rural areas covered by the PLPT, with an increase of 44.1% in the purchase of television sets (26.3% purchased new sets and 17.8% bought them secondhand), a 35.7% increase in the purchase of refrigerators, 27.7% in the purchase of radios, and 24.8% in the purchase of freezers, cooling fans and liquidizers. Furthermore, health centers have been equipped with refrigeration, enabling them to stock vaccines, and electricity in schools has enabled the use of computers and lessons outside daylight hours. Around 23.4% of the families supplied with electricity stated that at least one family member would have migrated from the area had it not been for access to electricity (this amounts to approximately 200,000 people).

According to the Ministry for Mines and Energy, since the commencement of the Program to July, 2009, around 10,000,000 people, in all Brazilian states, were benefitted by the Luz para Todos Program.

From 2003 to September 2008, work on the PLPT generated around 250,000 jobs, directly and indirectly, and used 600,000 transformers, 3.9 million masts and 750,000 km of electricity cables.

In the Northern region of the country, where the difficulties are enormous, there is still much to be done. The logistical problems posed by the long distances to be covered and the difficulties of access are further aggravated by the region's tropical climate – rainy and humid, which leads to some areas being completely isolated from the rest of the continent between November and April.

The increase in cost of new connections has been a significant issue for the distributors in terms of meeting the universalization targets in rural areas: the company's service costs increase when it begins to serve isolated locations. Furthermore, the increased

[4] RGR – Global Reversal Fund (*Reserva Global de Reversão*) – Set up by Decree No. 41,019 of February 26, 1957 to provide funds for the nationalization of electricity services. The fund is managed by ELETROBRÁS and is to be wound up at the end of the 2010 financial year, in accordance with the amended wording of Law 9648 of May 27, 1998.

[5] The original target of 2008 was extended to 2010 by Decree No. 6442 of April 25, 2008 as further family groups with no access to electricity were identified during the Program, and there were also delays in implementation in some states.

[6] It is now known that the there was an underestimate of the universalization targets at the time the Program was launched of the number of people who did not have access to electricity services. This was mainly due to: (a) ignorance on the part of the concessionaires of the real need to supply isolated populations in remote locations, who were frequently not registered with the relevant Local Authority; (b) lack of information from the Brazilian Geographical and Statistics Institute IBGE on the rural populations of the Northern Region; (c) differences between the Electricity Sector and the IBGE as to the definition of dwellings with access to electric lighting: the methodology of the IBGE classifies as a dwelling that has access to electricity one which has a small diesel generator or gas system, whereas the electric sector relies only on the number of connections, or the number of consumers served by the concessionaire; (d) use of IBGE data from the 2000 census which was already outdated by the time the program was launched in 2004; (e) the emergence of new residential areas, recorded in guidelines for electricity supply, that had not been recorded in earlier statistics; (f) the fractioning of properties; (g) rural property-holders who wait for the program to reach the areas in which they are located in order to take advantage of the benefits. Furthermore, the established targets were, frequently, presented at political events, without prior evaluation of the whether it was realistically viable for the concessionaire to meet them.

[7] CDE – Conta de Desenvolvimento Energético (Energy Development Account) – Established in 2002 with funds rose from the annual charges for the use of public assets, paid on a quota basis by the agents who supply electricity to the final consumers. The aim was to promote rural electrification throughout the national territory, on a *dead capital* basis. This fund has also been used for several other purposes, in accordance with the determination of the Federal Government.

[8] US$1.00 = R$1.87 in August 28, 2009.

[9] Currently, the area known as *Amazônia Legal* corresponds to the whole of the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins and part of the state of Maranhão.

Table 1
Number of consumers connected by the light in the country program and cost of new connections in Bahia, classified by distance to the network and population dispersal.

Degree of Dispersal (mast/consumer)	Number of Consumers / Network Cost per Consumer - R$ / Distance from the network in km						N°. consumers served
	0 - 1	> 1 - 5	> 5 - 10	> 10 - 20	> 20 - 50	> 50	
fi 0,5	38,458	6,283	264				45,005
	282.23	391.82	545.48				
> 0,5 - 1	13,625	8,078	1,648	77			23,428
	868.3	874.56	963.81	1,006.97			
> 1,1 - 2	9,881	8,282	2,673	852			21,688
	1,705.45	1,734.53	1,744.83	1,920.20			
> 2,1 - 4	7,566	5,433	3,069	1,367			17,435
	3,182.91	3,197.77	3,261.31	3,576.98			
> 4	4,757	2,801	3,005	1,847	130	70	12,610
	11,248.70	11,727.19	12,859.73	17,631.10	18,409.39	76,192.16	
Total	74,287	30,877	10,659	4,143	130	70	120,166

demand for equipment, particularly cables and transformers, as a direct result of the Luz para Todos Program has led to their becoming more expensive. It is estimated that the average connection cost within the ambit of the first PLPT contracts increased from approximately R$ 2000 per household in 2004, to R$ 5000 in 2007.

The issue is even more critical in relation to the Amazon hinterland: the average cost per household is R$ 10,000. The situation is further aggravated by the high rate of non-payment by consumers, which further undermines the concessionaire's profitability.

Furthermore the concessionaires in the Northern region are almost all state owned companies. The process of acquisition of equipment takes longer for them due to the legal requirement to tender out the provision of goods.

A study undertaken by the State of Bahia [7] demonstrates that the difficulties in the electrification of communities that are distant from existing distribution networks had already prevented a greater universalization of electricity services during the Luz no Campo Program. The information contained in Table 1 shows that 75,000 of the approximately 120,000 consumers connected by the Program in the state of Bahia lived less than one kilometer away from the existing network, with network charges per consumer varying from R$ 282.00 to R$ 11,250.00. On the other end of the scale, 70 new consumers were over 50 km away from the network, with a network charge of R$ 76,190.00 per consumer. The same table sets out five levels of dispersal of new consumers, and also shows that of the total number of new connections, only around 10% were connected at distances requiring over 4 masts per consumer.

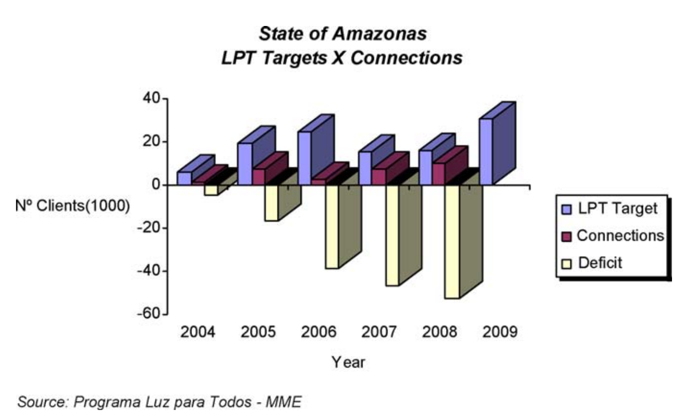
The major difficulties in the expansion of the Luz para Todos Program in the State of Amazonas have delayed universalization, impeding the meeting of the established targets by the end of the Program in 2010.

Graph 2 sets out the targets decided upon in conjunction with the State Government of Amazonas for the PLPT for the 2004–2009 period. It also shows the total number of connections for the period[10] and the annual accumulated difference between the targets and connections actually made (*deficit*). The figures for 2009 are the forecast connections for the year plus connections already underway in April 2009.

The lack of experience of some agents in implementing the Program has also been responsible for connection delays. Furthermore, political and administrative interference has also hampered efforts to meet the targets.

With around 24,000 connections having been made since the beginning of the Program, there is an accumulated connection deficit of over 50,000 consumer units in the state of Amazonas in 2009. The forecast target of 30,000 for this year is totally unrealistic, particularly given the manner in which the Program has been administered, particularly in remote regions. The MME (Ministry of Mines and Energy) forecasts that over 80,000 homes will be served in the state of Amazonas via aerial or sub aquatic extension of the network or photovoltaic panels (central or individual).

Some issues still need to be dealt with. For example: in several places the arrival of electricity did nothing to increase household income, and many families are unable to pay energy bills, even the nominal amounts charged to persons classified as *Low Income*



Graph 2. LPT targets, connections and the deficit of connections in the State of Amazonas – 2004–2009.

[10] The figures for 2008 include connections made up until April 2009.

(*Baixa Renda*). The cost of such connections is already a potential threat to the financial-economic equilibrium of the concessionaires and this non-payment aggravates the situation even further. This is one of several questions that the Program has failed to address: how to provide electricity in a manner that is capable of improving the prospects of the population groups benefitted being able to take responsibility for continued supply without prejudicing the distribution company.

The alternative we propose in this paper is a Program to Supply Isolated Communities (*Programa de Atendimento às Comunidades Isoladas*), drawn up specifically for this segment of the population, with the allocation of financial resources by the government, and which pays heed to local need and potential for income generation thereby contributing to the area's social and economic development.

The Ministry of Mines and Energy (MME) states that this perspective should be set out in the Project for Integrated Actions and Productive Use of Electric Energy (*Projeto Ações Integradas e Uso Produtivo de Energia Elétrica*) which is part of the Luz Para Todos Program.

This Project involves a range of strategic actions under multi-sector programs and resources aiming, essentially, to reduce poverty by means of the productive use of electric energy. The actions include, over and above the supply of electricity, the supply of water from communal wells, construction of schools, telecenters, and Community Production Centers (Centros Comunitários de Produção – CCP), with the combined efforts of various ministries and banks, for productive use of the energy for the generation of income for the local population.

According to the MME, the new projects will give priority to decentralized generation based on local and renewable sources and to the mitigation of environmental impact through the use of mini and micro-hydroelectric plants, hydrokinetics systems and the generation of bio-combustible fuel, in addition to the installation of non-conventional networks with the use of isolated and sub-aquatic cables, in accordance with the established priorities of the MME in meeting the needs of isolated communities. In reality, however, the rhythm of these initiatives is very slow *vis-a-vis* the needs of the target communities.

We set out below, by way of example, the Luz Para Todos Project for the Terra Preta do Limão Community in the state of Amazonas, where 239 domestic unit connections were made, benefiting 1800 people, via an extension from the network to the municipality of Barreirinha [8].

It was noted, from research in the community, and from completed questionnaires and reports, that access to energy had not led to the public policy targets for sustained growth being reached, nor to the "development of the community". According to some of those benefitted by the Program in the region, electricity is used for entertainment, communication (news), illumination, the pumping of water, refrigeration and air-conditioning. It has not, however, been possible to set up small businesses such as "a bicycle repair shop or small market, as *the supply of energy is inadequate* [for this]".

The following positive indicators were noted in the Community, in accordance with replies to a questionnaire sent to residents, following the implementation of the PLPT:

- Reduction of illnesses following the advent of piped water.
- The setting up of Health Centers, medical and dental services and the hiring of health professionals.
- Improvement in education provision, with lessons provided at night, lessons on technology and IT, amongst other improvements.
- Conservation of foodstuffs, the sale of frozen food, improvement in the quality of food products.
- The possibility of access to energy 24 h a day, enabling public lighting, commerce, and the purchase of domestic electronic goods.
- Contact and access to other regions via TV news.
- Fresh job opportunities after daylight hours.

However there were also reports of the following negative aspects:

- Non-efficient use of energy.
- Lack of improved employment and income potential.
- Increased 'idleness' and reduced motivation and related social problems (bars, alcoholism, drugs).

2.2. Lessons learnt

The following are some of the most important lessons learnt from the programs for rural electrification and universalization of electricity services in Brazil:

- Rural electrification needs to be tied in with social inclusion.
- The arrival of electricity should be combined with advice and instruction as to efficient use.
- It is essential that the program to be implemented in isolated areas should be thought out bearing in mind the need for continued supply without prejudice to the distribution company.
- The market should be informed in advance as to the future demand for equipment and services to avoid shortage and price hikes that undermine the continuation of the program.[11]
- The program aimed at serving the needs of isolated communities should be specifically drawn up for this population in accordance with their particular needs and potential.
- Fresh resources should be allocated to action aimed at universalization and the substitution of fossil fuels in the generation of electricity. The RGR – which provides approximately 15% of the resources used in the PLPT – comes to an end in 2010. The resources of the CDE are totally tied in with other aims.
- The program to be used in rural and isolated communities should give priority to training for the activities that will be undertaken, with a view not only to the sustainability of the initiatives but also the autonomy of the local population.

3. Isolated systems of electricity generation in the Amazon Region

The Brazilian Isolated Systems,[12] predominantly thermal plants dispersed in the Northern Region, supply an area covering approximately 45% of national territory and around 3% of the national population, in other words, approximately 1.6 million consumption units.

The Isolated Systems in Amazonia (Fig. 2) have specific characteristics such as: a reduced and disperse consumer market with a high rate of suppressed demand; the costs of generation, which is generally based on the use of fuels derived from petroleum, frequently transported by river; returns which are insufficient to cover the operational costs of the concessionaires; the prohibition on passing several operational costs on to the tariff, due to the low level of income of local consumers, in addition to

[11] Traditionally, the electricity sector, when it published its 10-year Electricity Plans (Planos Decenais de Energia Elétrica), also set out a list of the necessary equipment and materials necessary for the construction of future plants, so that potential suppliers could make the necessary arrangements.

[12] *Isolated Systems:* electricity systems which are not part of the Interlinked Grid National System (Sistema Interligado Nacional).

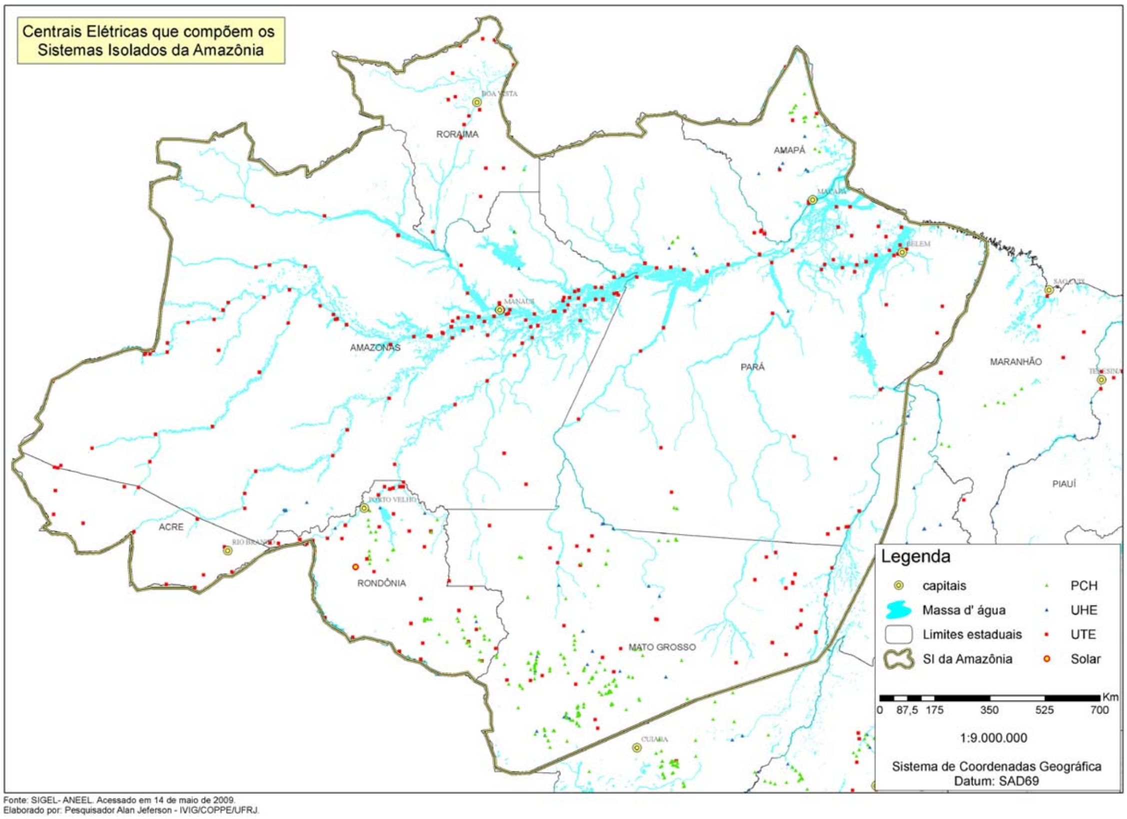


Fig. 2. Electricity systems that make up the Isolated Systems.Source: ANEEL/SIGEL.

increased technical loss in generation and distribution systems leading to significant financial loss [9].

Opting to extend the network in the immense Amazon hinterland frequently leads to kilometers of cable and dozens of masts to supply a single dwelling, due to the vast territorial dispersal. De-centralized, and, frequently, individual generation is an attractive alternative for the region, compared to the high costs of transmission and distribution.

The energy supply model implemented in Brazil based the generation of energy for remote communities on fossil fuels, as can be seen in Fig. 2; the basic grounds for this were: *relative* low initial investment cost, the *advantages* of the use of liquid fuels derived from petroleum, the *relatively* low need for maintenance of generating equipment, in other words, a series of *facilities* that are no longer present. This pattern is maintained nowadays only due to the lack of priority given to public policies for the region.

There are constant interruptions to the supply of electricity in the communities served by Isolated Systems. The quality of the energy is low and several systems are not supplied 24 h a day. Furthermore, several remote communities are not served at all.

Table 2
Isolated generating systems – 2009.

	Total	Northern region	%
Hydraulic units			
No. of hydro plants	13	13	100
Capacity of hydro plants (MW)	544	544	100
No. small electric plans (under 30 MW)	40	37	93
Capacity of small hydro plants (MW)	143.7	141	98
Thermal units			
No. of thermal units	1.230	1151	94
Nominal capacity (MW)	3,335.80	3.299	99

Source: GTON – Operational Plan 2009 – Isolated Systems, Janeiro 2009.

As set out in the following charts (Tables 2–4) the current Generating Plants of the country's Isolated Systems is largely thermal, and almost totally located in the Northern region (see Chart 2).

Table 3 sets out the forecasts for thermal generation in the Isolated Systems in 2009, with limited use of biomass as it shows, and Table 4 sets out the forecast consumption of fossil fuel and the corresponding thermal generation in MW h.

Table 3
Forecast for thermal generation – Isolated Systems – 2009.

Generating source	Thermal generation average (MW)
Diesel oil	336.4
Light oil – OCTE[a]	177.7
Combustible oil	378.3
Heavy oil – PGE[b]	103.6
Total thermal from combustible generation	996.0
Total thermal generation from steam	18
Total thermal generation from biomass	5.9

Source: GTON – Operational Plan 2009 – Isolated Systems, Janeiro 2009.

[a] OCTE – fuel oil for electricity turbine generators (light oil).
[b] PGE – heavy oil for electricity generation.

Table 4
Forecast thermal generation and fuel consumption – Isolated Systems – 2009.

Generating source	Fuel consumption	Thermal generation (MW h)
Diesel (10^6 l)	831.3	2,947,128
OCTE light oil (10^6 l)	530.7	1,556,848
Combustible oil (10^6 kg)	760.6	3,314,156
Heavy PGE oil (10^6 kg)	180.6	907,200

Source: GTON – 2009 Operational Plan – Isolated Systems, Janeiro 2009.

Table 5
Thermal generating units – 2009 – State of Amazonas.

Configuration by range of capacity	Number of units
Manaus	170
Between 500 kW and 1 (MW)	48
Between 1 and 2 (MW)	68
Between 2 and 20 (MW)	36
Between 20 and 60 (MW)	18
Hinterland of Amazonas	426
Less than 100 (kW)	28
Between 100 and 500 (kW)	175
Between 500 kW and 1 (MW)	93
Between 1 and 2 (MW)	120
More than 2 (MW)	10

Source: GTON – 2009 Operational Plan – Isolated Systems, Janeiro 2009.

As can be seen, the forecast fuel consumption for this year is 1.3 billion liters of medium oil (diesel and OCTE) and almost 1 million tons of heavy oil (combustible oil and heavy PGE).

Thermoelectricity is generated in the Isolated Systems via turbines in the larger municipalities and a large number of small diesel oil generators that are wasteful in terms of fuel due to their age and low efficiency.

The Generating Park of the Amazonas Energia company (a merger of the former Manaus and Ceam) is made up of the Balbina Hydroelectric Unit, with 5 machines of 50 MW, 170 thermal units in Manaus (capital of the state of Amazonas) and 426 small thermal units hinterland, with the configuration shown in Table 5. For 2009, the Amazonas state will be supplied, besides the hydro plants, by 1181.9 MW from Thermal Power Generation in Manaus (capital of the state) and 328.3 MW hinterland of the state.

4. The fuel consumption account – Conta de Consumo de Combustíveis – CCC

The fuel used in the Isolated Systems is subsidized via the Fuel Consumption Account – CCC. This account was set up in 1973, and is still in force today, its object being to enable the offer of electricity at moderate prices in the most distant regions of the country, and in particular in the Isolated Systems of the Northern Region. It operates via a mechanism of apportionment between the utilities of the National Interlinked System (Sistema Interligado Nacional), of the consumption cost of the fossil fuels used in thermoelectric generators transferred to final consumers within Brazil, after deduction of an amount corresponding to Equivalent Hydraulic Energy. The resulting fund is managed by *Eletrobrás*, and made available to the utilities on the basis of quotas which are proportional to the amount of energy sold.

Whilst the CCC mechanism enables the supply of electricity to isolated communities, it also inhibits the competitiveness of renewable sources of electricity in the region, as it alters the relative price of the options. One way of modifying the current scenario would be to use CCC resources to enable the viable supply of renewable energy to isolated communities, on a long term sustainable basis, rather than subsidizing fossil fuels.

In 2008, the total CCC resources amounted to approximately R$ 3.5 billion reais [10] and for 2009 ANEEL – the Brazilian National Electricity Regulatory Agency (Agência Nacional de Energia Elétrica) published Confirmation Resolution No. 792 with a budget of R$ 2.5 billion reais for the CCC.

Budget variations in the CCC are essentially based on hydrologic forecasts, the expansion of the market, fluctuations in the price of fuel and the specific consumption of generating centers, leading to greater or lesser fuel consumption, with a direct impact on generation costs.

5. Electric energy and renewable sources in the Amazon Region

The major issue in relation to Amazonia is how to use the vast wealth of the region to promote economic development, with social inclusion, without impacting on the environment.

This requires specific studies focused on Amazonia leading to detailed knowledge of its vegetation species and potential, with a view to non-destructively drawing on the natural resources in order to enable development for the local population.

In Amazonia, the application of the concept of sustainable development should address, in particular, the concern about the rate of destruction of the vegetation layer, whilst integrating actions that lead to the generation of resources, income and monetary flow remaining in the region promoting the economic development of the population.

There is a diverse range of renewable primary energy sources in the Amazon Region, as well as biodiversity that is unequalled anywhere on the planet. Solar energy, which is abundant throughout the year, wind, in certain locations and water currents which have real potential in terms of energy generation.

The mapping of solar energy resources by Solar and Wind Energy Resource Assessment – SWERA [11] indicated a high flow of

Date of implementation (commencement)	*June 1, 2005*
Conclusion of implementation	*November 25, 2005*
Investment	*R$472,422*
Network (km)	*16.30*
Masts	*219*
Transformers	*18*
Installed Capacity – kVA	*90*
Meters	*239*
N°.of Interviewees	*40*
Purchasers of Dwelling Electrical Goods	*88%*

Source: Cavalcante, 2007 - A Contribuição do Programa Luz para Todos no Desenvolvimento Sustentável do Amazonas

Chart 2. Characteristics of the Terra Preta do Limão Community Project, AM–Luz Para Todos Program.

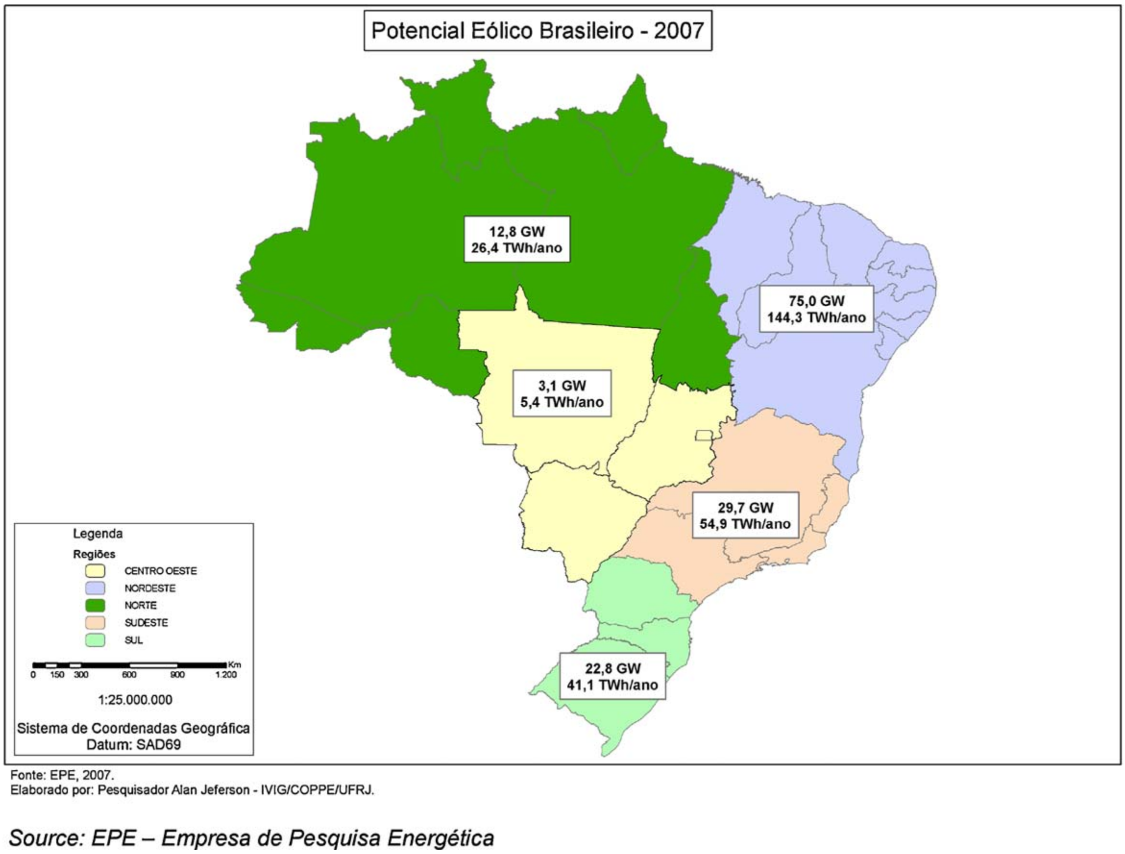


Fig. 3. Brazilian wind-power potential – 2007.

solar radiation in the Northern Region of the country – around 5.5 kW h/m^2.

The estimated solar potential has low inter-seasonal variability, and is adequate for the technical standards recommended for hybrid mini-system technology (diesel/solar photovoltaic).

There is significant potential for the generation of energy from forest and agricultural residue in Amazonia. The extent of such residue is being investigated, and information available to date points to biomass as a major source of energy for the region, with the substitution of firewood by sustainable use of resources applying various technologies. The immense variety of vegetable species requires further research into vegetable oils that may be used as an alternative to mineral oils, either *in natura*, processed or transestrified – biodiesel [12].

Compared to the North–East, South and South–East regions, the potential for generation of electricity from wind is significantly lower in the Northern region, as can be seen from Fig. 3. Only in a few coastal areas is it possible to wind power for energy generation.

The region has significant hydroelectric potential – around 93 GW out of a total of 247 GW in the Country [13] – almost 38%; however the relief is unfavorable, leading to the possibility of the use of micro hydroelectric stations or hydro synthetic turbines powered by the speed of the river.

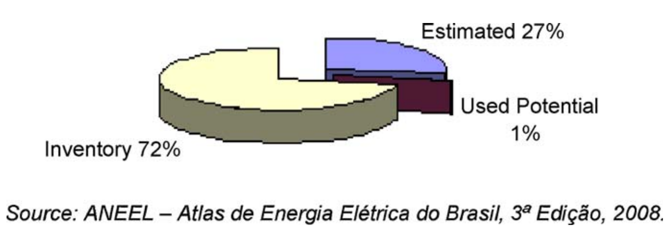


Fig. 4. Hydroelectric potential of the Amazon River Basin – 2008. (Used potential' (Aproveitado), in this context, includes power plants in existence, underconstruction or for which the concession had already been granted in December 2005. 'Inventory' (Inventário) in the figure indicates the minimum study made of potential.)

Fig. 4 sets out the Hydroelectric Potential of the Amazon River Basin, showing that only 1% is use for energy generation.

It is not only the issue of the universalization of electricity services that should be regarded as a priority for Amazonia, but also the substitution of fossil fuels by renewable sources that are available locally; such substitution generates positive impacts on the local and national economy and reduces the emission of pollutant gases into the atmosphere, breaking the paradigm of the generation of electricity from fossil fuels in the region.

Incentives for the implementation of renewable projects for electricity generation should be the result of express policy such as the (temporary) reduction of duties on high efficiency generating equipment and/or legal obligation to generate energy from renewable sources as part of the energy mix of each utility. This is only means of providing a viable and attractive option to the CCC incentives for fossil fuels.

Favorable conditions developed for new technological options, in addition to fine-tuning the regulations that formulate a reduction indicator as an incentive for diesel generation.

6. A proposal for autonomy and sustainability of the populations

Due to the high rate of dispersal of the population in Amazonia, and the major distances, a liter of diesel oil transported to generate electricity may mean using 2 l of fuel, which is far beyond the purchasing power of local consumers.

The issue of logistics, emissions from the burning of fossil fuels and the difficulties posed by money transfer from oil and diesel imports, are major challenges to be overcome in the strategy for

management of energy to remote and isolated communities in Brazil.

The management of energy sources is unquestionably highly relevant to the sustainable development of the local population. The current economic model in Brazil is sustained by a structure of supply and demand for energy that intensifies inequalities and limits progress towards fairer and more evenly distributed growth.

There is an urgent need for the establishment of a new policy of occupation, production and development of Amazonia. The current economic model applied to the region, based on predatory agriculture and extensive cattle raising has already been exhausted. As the Northern region is home to a large number of isolated communities which have distinct socio-cultural and geographical characteristics, access to energy services, as part of the goal of universalization, should be implemented in a manner that is distinct from the generation and distribution techniques/ technologies adopted in other regions of Brazil.

The development policy aimed at these communities should be based on viable and sustainable solutions drawn from in-depth knowledge and understanding of the Amazon Region, its vegetation, potential, characteristics and the vocation of each community, in addition to the lessons learned in previous projects implemented in the region.

The participation of the community, at several levels, in various forms, and at all stages of activity, is an essential component of the model proposed. The local population must be given priority in the application of natural resources (or access to them) and to a proportional share of the benefits generated by the local biodiversity.

Furthermore, although it falls to utilities to undertake expansion of the electricity grid to the most isolated and remote populations within their concession area, it is the State's duty to promote universalization and to define clear financing mechanisms that enable the necessary work to be undertaken without prejudice to the economic-financial equilibrium of the concessionaires.

Thus, an effective electrification plan must be included in a new regulatory context that addresses issues that have hindered an increasing in connections, such as:

- The lower quality of electricity supply in the Amazon Region, and generally, in isolated regions; the issue of the right to equal treatment ('isonomy'),[13] in other words, the rights of citizens throughout Brazil to electricity of the same quality as that supplied to other regions, meeting quality standards to be extensively discussed and taken into account.
- The issue of continuous current provision, enabling the supply of photovoltaic energy without the need for a CC-CA converter (which is burdensome and prone to operational difficulties).
- The need to consider the specific aspects of the various technologies available, and the management issues of decentralized generation systems, as well as the characteristics of the rural communities to be benefitted.
- The need for access to financial, credit and tax incentives established for generation to be tied in with certain basic attributes to be required of the projects, other than cost (such as social, environmental or technological targets), so that the greatest incentives will be offered to projects that contain the most attributes. In this way projects may attract resources from outside the energy sector.
- The use of a *pre-paid* mode for electricity supply in areas where charging customers is an excessive burden for electricity companies.

[13] Isonomy – the principle, set out in the Brazilian Federal Constitution, whereby all persons are equal before the Law, so that there can be no distinct treatment of persons who are in the same situation.

The technological option to be adopted to supply energy to Amazonia will only succeed in reducing the disparity in the conditions in which local communities live if it is accompanied by institutional measures such as financing to cover initial costs and system maintenance and policies that promote local development. The local populations must be totally involved in the decision making processes as to the energy systems to be set up as they will be the ones who will ultimately use, maintain and pay for the energy services. Cultural aspects must be taken into account in the social transformation of these societies.

The *electric energy vector* is vitally important to the process of integrating Amazonia to national development. Electricity is also highly important in terms of education in rural areas as it enables lighting at night for study, and classes or training events at night, outside working hours.

The logistics of the acquisition of raw material and the transport of goods to the consumer market, along with access to credit (or lack thereof) are other issues which need to be addressed in order to enable the effective inclusion of rural populations in the Brazilian economy; these variables are essentially dependent on the implementation of infrastructure and the economic development that should follow on from the arrival of electric energy and the related possibilities for agriculture, cattle-raising and industry in the rural areas.

The process is dependent on certain key factors: the support of all spheres of government (federal, state and municipal) and stimulus for directing local produce to the markets, thus establishing the clear correlation between income generation and conservation.

Investment decisions for the generation of electricity for the communities examined in this paper should follow different criteria to those traditionally adopted given the range of benefits that the projects in question can provide, including the reduction of greenhouse gases, amongst others.

7. Conclusion

As was observed above, the proposed electrification of isolated and remote rural communities in Amazonia should be preceded by effective planning, including the establishment of management mechanisms guaranteeing the sustainability of electrification projects.

The diversity of situations observed in the process of universalization of access and use of electric energy in rural Brazil, particularly in the Northern region, demands a range of solutions and alternative technologies. Studies, research and pilot projects have already been exhaustively developed and implemented in isolated communities in the Amazon, producing results clearly pointing to the needs for implementation on a commercial scale.

The major objective to be pursued is to ensure that these populations are included in modern society and participate in the development of the country as a whole, and in the worldwide trend towards improvement in the wellbeing of such population groups.

The basic premise for the management of supply to communities in the Amazon should therefore be that there is no single all-encompassing solution for the generation of electricity, but that each community should develop its own response, in accordance with its specific characteristics and potential. The supply of electricity should then be the result of clear and long-term compromise between local actions and the conservation of natural resources, with concrete and direct benefits to the local population, such as increased quality of life as evidenced in such aspects as health and education, as well as the reduction of anthropic pressure on the environment.

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